CHANGES IN RIPARIAN VEGETATION IN THE SOUTHWESTERN UNITED STATES:
Historical Changes Along the Mojave River, California

USGS GROUND WATER RESOURCES PROGRAM

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The alluvial aquifer of the Mojave River is the primary source of water for domestic supplies and irrigation in the western Mojave Desert. The river also supports riparian communities unique to the Mojave Desert ecosystem. North of the front of the Transverse Ranges, perennial flow extends reliably past Lower Narrows and extends past Helendale only during periods of storm runoff. Ground water supplies both domestic and irrigation to water users in the basin, particularly upstream from Upper Narrows and to a lesser extent between Barstow and Camp Cady. A model of the ground-water flow system, recently completed by Stamos and others (2001), confirms that ground-water levels in the basin have been declining steadily in the latter part of the 20th century as previously known from water-level measurements. Ground-water changes are of concern to land management agencies because they have led to decimation or elimination of riparian vegetation in some reaches (Lines, 1999). Some water is imported into the basin to artificially recharge the alluvial aquifer; this water also benefits riparian ecosystems. The purpose of this poster is to present initial findings on long-term changes in riparian vegetation along the Mojave River.

Repeat photography documents long-term changes of riparian species along the Mojave River through the last 137 years. The first photographs of the Mojave River were taken by Richard D'Heureuse, a member of the California Geological Survey expedition of 1863, using a large-format, glass-plate camera. The expedition began in San Bernardino and travelled the Mojave Road from Victorville to the Colorado River. D'Heureuse photographed scenes that included the river and its attributes at Point of Rocks near present-day Helendale, at two sites near Barstow, at the old Camp Cady, at Afton Canyon, and at the site of present day Zzyzx on the west edge of Soda Lake playa. David Thompson, a hydrologist with the U.S. Geological Survey, worked on issues related to surface and ground water hydrology of the Mojave River in the 1910s and 1920s (Thompson, 1929). He photographed key reaches of the Mojave River, including the Upper and Lower Narrows near Victorville, the reach upstream of Helendale, Barstow, the Yermo area, and the reach between Camp Cady Ranch and Afton Canyon. Historical photography, which was black and white, documents only the larger-stature woody species. In the case of the Mojave River, these species are cottonwood (*Populus fremontii*), Goodding or black willow (*Salix gooddingii*), mesquite (*Prosopis glandulosa* and minor amounts of *P. pubescens*), and non-native tamarisk (*Tamarix ramosissima*). Smaller-stature species that appear in some of the photographs include coyote willow (*Salix exigua*) and seep willow (*Baccharis glutinosa*). As mapped by Lines and Bilhorn (1996), many other woody riparian species exist in the basin, mostly in small amounts. Some notable species include sycamore (*Platanus racemosa*), velvet ash (*Fraxinus velutina*), cattails (*Typha latifolia*), and bulrush (*Scirpus* sp.). Invasive non-native species of note, other than tamarisk, include giant reed (*Arundo donax*), which was observed at Lower Narrows.

INITIAL OBSERVATIONS

Changes in riparian communities along the Mojave River are highly variable, ranging from large increases in biomass of cottonwood trees to complete elimination of riparian species. The largest increases occurred in the area that now is Mojave Narrows Regional Park, upstream of the Upper Narrows between Victorville and Apple Valley. Riparian trees in this reach were mostly Goodding willows in 1917, and now cottonwood dwarfs this species in abundance and stature. Few woody plants were present in the Lower Narrows in 1917, with the exception of coyote willow, but many new cottonwood and sycamore, as well as tamarisk, are now in this reach. South of Helendale, the historical photographs show the riparian corridor in the distance, but it is clear from a comparison of the photographs that cottonwood trees increased in height between 1917 and 2000. At Barstow, native riparian vegetation, which was mostly mesquite, has been replaced by tamarisk. Between Barstow and Camp Cady Ranch, several camera stations could not be relocated because of unstable sand dunes and channel margins, but most of the mesquite and other riparian trees that grew in this reach in 1917 are dead. At Camp Cady Ranch, riparian vegetation increased between 1919 and 2000, although declines upstream and downstream from the camera stations suggest that the vegetation in this reach is in peril. Finally, little riparian vegetation was present in Afton Canyon in 1863, but the few large treesÑwhich likely were cottonwood or Goodding willowÑare now gone. Most of the decreases are likely the result of local ground-water pumping; the headwater dams have not had a significant impact on flow in the Mojave River other than to attenuate flood peaks (Lines, 1996).

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LOWER NARROWS

(1917). Thompson took this downstream view of the Mojave River from the deck of a highway bridge. Most of the trees appear to be Goodding willows, leafless in the winter season, and cottonwoods appear at several places, particularly on river right (right side). The channel is unconfined by bedrock here and is very wide, possibly in response to recent floods (David Thompson 443, USGS Photo Library).

(October 24, 2000). Because the bridge was replaced at a higher elevation than the one that was present in 1917, our match is too low. Seep willow and cattails dominate the view, with mature cottonwood trees appearing behind them to the right and left (Dominic Oldershaw, Stake 2112b).

(1917). In this upstream view from the same bridge, the main railroad between Salt Lake City and Los Angeles is at left. The shrubs along the channel appear to be mostly coyote willow and seep willow. What appear to be small cottonwood trees are in the middle distance (David Thompson 444, USGS Photo Library).

(October 24, 2000). Because the old bridge was replaced at a higher deck elevation, our match is from a bridge pier and is too low. Riparian vegetation has increased dramatically, blocking most of the view. A few cottonwoods appear on both river left and right, and various herbaceous riparian species are in the foreground lining the perennial stream. Beaver ponds also are present, and the beaver are killing some of the smaller trees in the upstream reach. The tree in the foreground is a sycamore, and several other sycamores are in the reach upstream. The occurrence of sycamore is highly unusual for this part of the Mojave River (Dominic Oldershaw, Stake 2112a).

UPPER NARROWS (VICTORVILLE)

(1917). Thompson photographed this upstream view of the Mojave River at the Upper Narrows as part of a 360¡ panorama. The leafless trees indicate the season is winter. The band of trees nearest the photograph appear to be mostly Goodding willows, but scattered cottonwoods are also in the view (David Thompson 445, USGS Photo Library).

(October 24, 2000). Until recently, the ranch shown in the center of this view remained in the same family that owned the property in 1917. Most of the has been grazed continuously, but likely at varying intensities, since 1917. Irrigation canals and water sources remain in approximately the same places, indicating that ground-water levels likely have not fluctuated significantly. Cottonwoods now dominate the trees in the view, and scattered Goodding willows are still present (Dominic Oldershaw, Stake 2110a).

(1917). This view, a pan to the left from the previous view, shows the main railroad line from Los Angeles to Salt Lake City as it passes out of the Mojave Desert into Cajon Pass and the Los Angeles basin. This single-track line is built on a berm that forces most surface water moving down the Mojave River to the left (east), although ground-water seepage appears in pools on the right. At left, the river floodplain has scattered Goodding willows. At right center, a railroad berm truncates a meander of the river, which now appears to be a disconnected slough with scattered trees along its banks (David Thompson 446, USGS Photo Library).

(October 24, 2000). Most of the land to the left (east) of the railroad is now in the Mojave Narrows Regional Park. Most of the trees visible are cottonwoods, although Goodding willows are still present. The fields in the right foreground are alfalfa, most surface water moving down the Mojave River to the left (east), although ground-water seepage appears in pools on the right. At left, the river floodplain has scattered Goodding willows. At right center, a railroad berm truncates a meander of the river, which now appears to be a disconnected slough with scattered trees along its banks (David Thompson 446, USGS Photo Library).

(1917). In this third view, a pan even further to the left from the two above, the trees appear to be mostly Goodding willow. A few cottonwoods appear in this view, particularly one at lower center, and some low shrubs along the channel appear to be coyote willows. The Mojave River is flowing towards the camera and has a wide, mostly denuded floodplain. Vegetation on this floodplain may be recovering from damages sustained in the 1916 flood, which was one of the largest on the Mojave River (David Thompson 447, USGS Photo Library).

(October 24, 2000). Most of the riparian forest shown in this view is in the Mojave Narrows Regional Park. The channel of the Mojave River has decreased to a mere fraction of its former width, in part because of regulation by dams upstream and the influence of the riparian vegetation. The trees present are mostly cottonwoods, but very large Goodding willows and other species are also present. The white haze in the background is smog over Cajon Pass (Dominic Oldershaw, Stake 2110e).

(1901). This downstream view towards Lower Narrows shows the former highway bridge across the Mojave River below the Narrows as well as the main railroad line leading towards Barstow. The trees in the middle distance and on river left are a mixture of cottonwoods and Goodding willows. The river channel is very wide, probably in response to 19th century floods including the 1891 event (M.R. Campbell 173, USGS Photo Library).

(October 24, 2000). Cottonwoods and developments now dominate the view, and the channel of the Mojave River cannot be seen. The old bridge was replaced twice, once by a similar two-lane bridge and then more recently by the four-lane bridge shown at lower right (Dominic Oldershaw, Stake 2111).

(1917). From a slightly different position than the 1901 view, above, Thompson photographed this downstream view along the Mojave River. A few ranches appear in the view, suggesting that grazing is a major land use in the floodplain. The river apparently is in flood. A fire is sending smoke from left to right across the background. Because of the architecture of their branches, the small, leafless trees along the river appear to be Goodding willows (David Thompson 450, USGS Photo Library).

(October 24, 2000). Development associated with downtown Victorville has changed the land use away from ranching, and no grazing occurs here. The perennial flow creates ideal conditions for the growth of riparian vegetation. The width of the channel has decreased by about two thirds, and the floodplain now is occupied by tamarisk, native willows, and herbaceous species. Cottonwood trees now dominate the river on both sides (Dominic Oldershaw, Stake 2110c).

HELENDALE

(1919). This view, from the east side of the Mojave River valley looking west, shows the Mojave River in the distance with low bluffs of fine-grained river and lake deposits on the skyline. The river is lined with trees that are likely a mixture of cottonwoods (taller, darker trees) and Goodding willows (lower, lighter trees). Both old Route 66 and the railroad cross the midground. The vegetation in the foreground is mostly creosote bush *(Larrea tridentata)* (David Thompson 441, USGS Photo Library).

(October 24, 2000). The trees along the river have increased in size and number despite ground-water pumpage in the vicinity. Cottonwood is now the most obvious species from this distance. The number of creosote bushes and other small shrubs in the foreground has greatly increased (Dominic Oldershaw, Stake 2114a).

BARSTOW

(1863). The California Geological Survey party of 1863, en route from San Bernardino to the Colorado River, paused at the future site of Barstow along the Mojave Road. The party called the low hill at left center ÒSugarloaf.Ó The foreground plants are creosote bush and cattle spinach *(Atriplex polycarpa)*. In the distance, trees line the channel of the Mojave River. Their stature suggests they likely are mostly Goodding willow, although a positive identification is impossible (Richard D'Heureuse 1905.16894ÑA, courtesy of the Bancroft Library).

(February 26, 2001). The camera station is on the edge of a railroad cut (behind the view) east of downtown Barstow, and vegetation and topography in the foreground and midground have been disturbed. Because of ground-water pumpage, almost the entire native riparian system in this area has been obliterated with the exception of mesquite hummocks on the north side of the river. The trees in the distance are a mixture of cottonwoods and non-native species, planted within a subdivision and irrigated (Dominic Oldershaw, Stake 2225).

(1917). Thompson took this upstream view of the Mojave River from a small hill on its north bank at the main road crossing at Barstow. Current deflectors appear at right center, designed to minimize erosion of the north bank and its roads. The low vegetation at left appears to be mesquite on sandy hummocks, and scattered shrubs of unknown species appear throughout the open, sandy channel. What appear to be cottonwood trees are visible in the distance (David Thompson 234, USGS Photo Library).

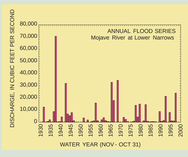
(October 22, 2000). Nearly all the native riparian plants in the previous view are dead, victims of ground-water overdraft in the reach upstream from Barstow. The low, hemispheric shrubs in the foreground are tamarisk, which accumulate eolian sand entrained from the open river bed and deposited around the trees. The vegetation at left is planted and irrigated, and most of the trees are non-native Athel tamarisk *(Tamarix aphylla)* (Dominic Oldershaw, Stake 2106b).

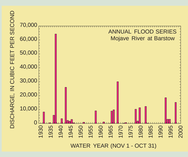
"MEETING OF THE ROADS" (near Yermo)

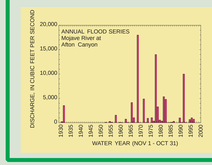
(1863). In 1863, the Mojave Road and the Spanish Trail met at the Mojave River east of Barstow, near the current site of Yermo. This photograph shows that the Mojave River was lined with short trees, probably Goodding willows. These trees suggest that reliable surface water once was present here (Richard D'Heureuse 1905.16894ÑA, courtesy of the Bancroft Library).

(April 25, 2001). During the last 138 years, hummocks with tamarisk, mesquite, desert willow *(Chilopsis linearis)*, and California scale broom *(Lepidospartum squamatum)* have replaced the willows. Although this photo is of mesquite-covered dunes with a few thorn bushes, tamarisk is the dominant woody shrub along this stretch of the Mojave River bed (Dominic Oldershaw, Stake 4085).

FLOWS IN THE MOJAVE RIVER







The Mojave River has its headwaters in the San Gabriel and San Bernardino Mountains of the Transverse Ranges of Southern California. The drainage areas at the long-term gaging stations are 513 mi² at Lower Narrows near Victorville, 1,290 mi² at Barstow, and 2,121 mi² at Afton Canyon. The river has a highly variable annual flood series, with some years having either base flow or zero discharge and other years having floods as high as 70,600 ft³/s. At right, the annual flood series, or largest peak discharge for each year, for three gages are given with the water year redefined to merge the effects of early fall tropical cyclones or cutoff lows into the previous year's record. Small floods and gaps in the gaging record cannot be resolved on these graphs, and Lower Narrows and Afton Canyon have perennial flow that also cannot be resolved on these graphs. The largest flood in the gaging record occurred in 1938, which was not an El Ni–o year; other years with large floods include 1891, 1905, and 1916, all of which were all El Ni–o years. In recent decades, the relation between flooding and El Ni–o has strengthened, with large floods in 1978, 1983, 1993, and 1998. The Mojave River only flows continuously from its source to its terminous in the Silver Lake Playa during these years.

The Mojave River and its tributaries have three dams that store water and provide some flood control for the reaches in the Mojave Desert (see map at far left). The Mojave River Forks Reservoir and Silverwood Lake reservoir, both completed in 1971, likely attenuate flood peaks, although they have no effect on annual runoff volume (Lines, 1996). The presence of these reservoirs may be the reason why the size of floods appears to have declined in the latter part of the 20th century, although this decline also could be the result of climatic fluctuations. Lake Arrowhead reservoir, built in 1922, provides only minimal flow regulation.

Artificial discharges to the Mojave River have had local effects on riparian vegetation. Water circulated through fish hatcheries, as well as municipal effluent, is released into the river in varying amounts in the reaches above and below Victorville. Of lesser significance is water imported from the California Aqueduct that is stored in Silverwood Lake and released into the Mojave River, and water released from the Mojave Water Agency's Morongo Basin Pipeline 5 miles below the Mojave River Forks Reservoir (Lines, 1996). Although base flow and smaller annual floods recharge water to the alluvial aquifer along the Mojave River, larger floods play a greater role in maintenance of the riparian ecosystem. Germination of riparian species occurs in the wet sediments deposited during floods, and the sequence of floods, as well as the amount of time between them, determines whether establishment occurs. Large floods also supply a greater quantity of water to trees on the distal margins of floodplains, aiding their survival. These floods also destroy smaller plants, and lateral channel change may undercut larger trees. Significant floods have occurred about every 5 years in recent decades and may have contributed to the increases in riparian vegetation in some reaches.

MANIX WASH

(1919). Manix Wash flows south into the Mojave River near the northern edge of the Cady Mountains. This view shows Manix Wash in the foreground and its confluence with the Mojave River (midground). Mesquite covers the dune hummocks in the wash. The Mojave River bed appears almost devoid of trees and shrubs in this view. Thompson also took photos a few hundred yards upstream (to the right). The upstream photos show patches of scattered trees, probably Goodding willows and cottonwoods (David Thompson 322, USGS Photo Library).

(March 2, 2001). The Manix Wash now has more shrubs, including many of the same mesquite hummocks present in 1919. Many of the other large shrubs and trees in the wash, tamarisk and desert willow, were uncommon in the early photo or not evident. No mesquite occurs beyond the confluence of the wash and Mojave River bed (midground). The Mojave River bed is now densely populated by tamarisks growing on hummocks of sand to the exclusion of all other species of shrubs and trees. Small remnants of native vegetation, including mesquite, can be seen on a few dunes at the north edges of the river bed (Dominic Oldershaw, Stake 116a).

OLD CAMP CADY

(1863). In the early 1860s, the U.S. Cavalry established several outposts at perennial water in the Mojave Desert for the protection of travellers along the Mojave Road, then known as the Government Road. The structure shown in this view is Camp Cady, on the north bank of the Mojave River northwest of the Cady Mountains. Behind and to the right of the fortification are riparian trees, which appear to be mesquite (plants just behind the fort), Goodding willows (both sides of fort), and coyote willow (right) (Richard D'Heureuse 1905-16894ÑA, courtesy of the Bancroft Library).

(October 23, 2000). Mesquite now blocks the view of the fort, which survives only in some broken foundations and a small commemorative sign. Mistletoe appears in some of these mesquite trees, which were very healthy at the time of this photograph. The foreground shrubs are cattle spinach. Cottonwood trees rise above some of the mesquite trees (Dominic Oldershaw, Stake 2107).

CAMP CADY RANCH

(1917). This view across the Mojave River floodplain, which was to become the Camp Cady Ranch (upstream from historic Camp Cady), shows a band of cottonwoods and Goodding willows along the Mojave River in the distance. This unbroken band conceals the river channel and indicates that the riparian system in the early 20th century was thriving (David Thompson 22, USGS Photo Library).

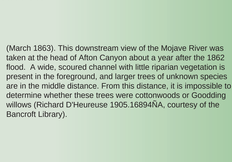
(October 25, 2000). Much of the midground vegetation was cleared for agriculture during private operation of Camp Cady Ranch. The ranch buildings and surrounding lands are now owned by the California Fish and Game Department, which ceased grazing and agriculture on the property shortly before this photograph was taken. The stature of the riparian community has increased as the cottonwoods have grown higher above the willows. Upstream and downstream from this reach, riparian vegetation is dying owing to ground-water pumpage (Dominic Oldershaw, Stake 2115c).

(1917). Downstream of Barstow, the Mojave River crosses a wide, sandy valley that, in 1917, had sand dunes and mesquite hummocks. Where the river approaches the northwest side of the Cady Mountains, its course apparently crosses a subsurface geological structure (either fault or geologic strata) that forces ground-water towards the surface. A zone of riparian vegetation consisting of mesquite, cottonwood, and Goodding willow was well established here in 1917. The channel of the Mojave River, which flows right to left across the center of this view, is relatively wide (David Thompson 15, USGS Photo Library).

(October 25, 2000). This view across the upstream part of the Camp Cady Ranch shows a section where mortality of mesquite has been high owing to upstream ground-water pumping, much of it immediately upstream from the reach in this view, and tamarisk has increased considerably in the midground. At the time of this photograph, tamarisk removal was occurring in this reach. Despite the mortality, riparian vegetation increased during the middle of the 20th century before the dieback because the channel of the Mojave River is much narrower (Dominic Oldershaw, Stake 2117).

AFTON CANYON

(October 25, 2000). Many changes have occurred in the last 137 years in Afton Canyon, spurred by large floods, cattle grazing, and manipulations of the riparian ecosystem. Changes to the riparian plants include the establishment of non-native tamarisk in the middle part of the 20th century, herbicide treatments to remove the tamarisk in the 1950s, and mechanical removal of tamarisk that began in the 1990s before this photograph was taken. Despite all these changes, riparian vegetation has obviously increased. The plants in the foreground are arrowweed *(Tessaria sericea)*, with a small Goodding willow in the center. Mesquite are also present in the middle distance. At this site, the channel of the Mojave River contains perennial water with reeds and cattails but no open channel (Dominic Oldershaw, Stake 2116).



(March 1863). This downstream view of the Mojave River was taken at the head of Afton Canyon about a year after the 1862 flood. A wide, scoured channel with little riparian vegetation is present in the foreground, and larger trees of unknown species are in the middle distance. From this distance, it is impossible to determine whether these trees were cottonwoods or Goodding willows (Richard D'Heureuse 1905.16894ÑA, courtesy of the Bancroft Library).

CRONESE VALLEY

(December 3, 1919). As the Mojave River exits Afton Canyon, the main wash continues east to Soda Lake. This view is downstream along a wash that drains north, a distributary of the Mojave River into the Cronese Valley in the background. Two dams, one in the foreground and one in the middle ground, block and channel water flow to the Cronese Valley. The dam in the foreground is filling with sediment, burying desert willows. Mesquite covers the dunes in the background (David Thompson 389, USGS Photo Library).

(February 26, 2001). In the intervening years, the dam in the foreground was breached, leaving a partial dike in the background. The large shrubs in the wash are desert willows, still alive but smaller and less robust than 82 years earlier. They are mixed with cattle spinach. In the middle ground, block and channel water flow to the Cronese Valley. The dam in the foreground is filling with sediment, burying desert willows. Mesquite covers the dunes in the background (David Thompson 389, USGS Photo Library).